~~C~~ D) a laser pulse bandwidth estimator estimating the laser pulse bandwidth, W_T, according to the formula $W_T = (W_R - (W_{FC} - W_R)$.

17. (currently amended) A photo lithography apparatus having a single material optical image projection lens without a second material of a different refractive index comprising;

A) a chromatic ~~abberation~~ aberration correction mechanism comprising;

B) a laser light source ~~proving~~ providing bursts of laser light pulses of a desired nominal wavelength wherein the nominal wavelengths of some of the pulses within the burst are slightly longer ~~then~~ than the desired nominal wavelength and the nominal wavelength of some of the pulses ~~with~~ within the burst are slightly ~~longer~~ shorter than the desired nominal wavelength such that the burst of pulses is within an average spectrum centered approximately at the desired nominal wavelength.

amendment

18. (currently amended) The apparatus of Claim 17 further comprising the burst of pulses also having an average ~~structural~~ spectral deviation from the desired nominal wavelength within a desired deviation.

PAGE 11/13 * RCVD AT 11/8/2005 5:55:21 PM [Eastern Standard Time] * SVR:USPTO-EFXRF-6/34 * DNIS:2738300 * CSID: * DURATION (mm-ss):04-58

Writer's Direct Telephone: 1-858-385-5298
Writer's Direct Facsimile: 1-858-385-6025
Writer's E-mail Address: mhillman@cymer.com

CYMER

January 6, 2006

Via Facsimile To: 571-273-1820

Examiner James Vannucci
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 2231301450

Re: U. S. Patent Application No. 10/670,406
Filing Date: Sept. 24, 2003
Title: BANDWIDTH CONTROL TECHNIQUE FOR A LASER
Applicants: Igor V. Fomenkov et al.
Group Art Unit 2828
Attorney Docket No. 2000-0015-06

Dear Examiner Vannucci:

Further to our telephone conversation on Thursday, December 5, 2006, please enter an Examiner's Amendment to amend the specification as follows according to paragraph designations in the above captioned application as published:

amendment

[0005] In the prior art, the typical feedback network is configured to maintain the nominal wavelength within a desired range of wavelengths. Typical specifications may establish this range at values such as ~~.A-inverted.~~ +/- 0.05 pm of a target wavelength such as, for example, 248,327.1 pm, as applied to the average of the wavelengths of a series of pulses referred to as "pulse window". A typical pulse window would be 30 pulses. Another typical specification is the standard deviation of the measured wavelength values for a series of pulses (such as 30 pulses). This value is referred to as sigma, .PHI., and is calculated using the standard formula for standard deviations. Also, sometime specifications are in terms of 3.PHI. which is merely three times the measured standard deviation. Typical 3 .PHI. specifications may be 0.15 pm.

[0029] In order to understand the impact of laser bandwidth on the lithographic process in the presence of chromatic aberrations, we started from investigation of the aerial image of a 180 nm isolated line. FIG. 3 shows how changing bandwidth affects the aerial image. (The image dimension is usually assumed to correspond to the 0.3 image intensity values.) For these simulations the following input parameters were used: NA=0.6, ~~.PHI.=0.75~~ $\sigma=0.75$, ~~8.sub.0=248.3271 nm~~ $\lambda_0=248.3271$ nm. Laser spectra with 0.5 pm, 1.2 pm, 2.1 pm bandwidths at FWHM and a monochromatic light source were used in this simulation study, and a chromatic

PAGE 2/4 * RCVD AT 1/6/2006 12:39:21 PM [Eastern Standard Time] * SVR:USPTO-EFXRF-6/29 * DNIS:2731820 * CSID:858 385 6025 * DURATION (mm-ss):01-42

Examiner James Vannucci
United States Patent and Trademark Office
January 6, 2006
Page 2

amendment

aberration focus response of ~~0.225.PHI.m/pm~~ 0.225μm/pm was assumed. As can be seen in FIG. 3, changes in the bandwidth causes noticeable changes in the image intensity.

[0030] The impact of laser bandwidths on critical dimensions (CD) variations of isolated lines with different sizes was evaluated using an aerial image threshold model. In this study the following input parameter settings were used: ~~.PHI.=0.75, 80=248.3271 nm~~, σ=0.75, λ_0=248.3271 nm aerial image threshold at 30%, NA=0.6, 0.7, and 0.8. The simulations were performed for isolated lines ranging from 240 nm to 140 nm. The chromatic aberration response was assumed at 0.225 ~~.PHI.m/pm.~~ μm/pm. As shown in FIGS. 4A, 4B and 4C, changes in the bandwidth (either increases or decreases) can result in substantial changes in the critical dimensions of the integrated circuit lines especially at higher numerical aperture values.

[0061] ~~N=integer, =0, .A-inverted.1, .A-inverted.2, .A-inverted.3~~ . . . N=integer, =0, ±1, ±2, ±3 . . . .

[0062] The values .lambda..sub.0, K.sub.1, FSR, and D.sub.0 are determined and stored at the time of calibration. The value for N is chosen such that:

~~*.lambda.-.lambda..sub.o*#-1/2FSR~~ $|\lambda-\lambda c| \leq \frac{1}{2}FSR$

[0084] This stack will produce linear adjustment of about 3.0 microns with a drive voltage change of 20 volts. This range is equivalent to about ~~.A-inverted.20~~ ±20 steps of the stepper motor.

[0087] In this embodiment these piezoelectric stacks provide very fine adjustment of the position of mirror 14A relative to mirror mount 86A. As in the above example, the total adjustment range of the piezoelectric elements 88A, 88B and 88C can be very small such as about 1.5 micron since large adjustments are provided by the stepper motor. Adjustment of this lightweight mirror with the three piezo elements over very small distances such as about 0.1 microns can be extremely fast in the range of about 10 microseconds. The mirror position can be adjusted by moving drive 88A in one direction and drives 88B and 88C in the opposite direction or by moving drive 88A only. As in the prior example, preferred control algorithms outlined in FIG. 12D calls for a stepper motor step if the piezo position reaches as low as about 30 or as high as 70 percent of the control range. This provides a control range without stepper motor movement of 160 nm which is equivalent to about 0.8 pm to about 1.6 pm (depending on whether one or three piezo drivers are used). Therefore, the very fast piezo controls have a range sufficient to control substantially all chirp variations which, as indicated in FIG. 15A, are typically within the range of ~~.A-inverted.~~ ± 0.10 pm. Larger wavelength changes are provided by the stepper motor.

17075 Thornmint Court San Diego CA 92127
Tel +1 858 385 7300 • Fax +1 858-385 7100

Examiner James Vannucci
United States Patent and Trademark Office
January 6, 2006
Page 3

amendment

[0095] For example, if the optical equipment for a scanner is designed for a bandwidth of 0.4 pm and because of a decrease in the fluorine concentration the bandwidth of individual pulses is 0.3 pm, mirror 14 may be dithered about its ~~nomial~~ nominal position to produce plus and minus shifts in the nominal wavelength of about 0.05 pm in order to maintain the same nominal wavelength with the effective increase by 0.1 pm. For a typical commercial excimer laser of the type discussed above, a change in the pivot position of mirror 14 of about 2 nm is required to produce a 0.05 pm shift in the wavelength. This change in mirror position is easily provided by the piezoelectric drivers referred to above and shown in the drawings as item 80. Typically in the integrated circuit fabrication each spot on the wafer is illuminated with a number of pulses usually in the range of about 30 to 150 pulses so that the dither rate should be sufficient so that each die spot receives about equal portions of pulses from both sides of the dither.

[0097] FIG. 10 illustrates the use of a segmented tuning mirror in which each of the 5 mirror segments is controlled by its own piezoelectric drive 14B1-5. Each of the segments can be operated very fast. This embodiment has an additional advantage of improving the bandwidth of the laser since each horizontal portion of the beam can be individually controlled. In a preferred embodiment, each segment is individually controlled with a feedback control system and software designed to maintain bandwidth within a desire range, such as within 0.03 ~~, A inverted.~~ ± 0.02 pm. This embodiment also has a PDA 124 for determining the position of each segment. The light is provided by a mercury lamp 114 where the UV light is passed through a slit 116 and a columinating lens 118. The beam in this case is expanded through the same beam expander used to expand the laser beam and five small lenses focus light from each mirror on separate parts of the PDA.

If you have any questions regarding these changes, please do not hesitate to contact me at the number listed above.

Very truly yours,

Matthew K. Hillman
Patent Attorney

MKH/sb

17075 Thornmint Court San Diego CA 92127
tel +1-858 385 7300 • fax +1 858 385 7100

PAGE 4/4 * RCVD AT 1/6/2006 12:39:21 PM [Eastern Standard Time] * SVR:USPTO-EFXRF-6/29 * DNIS:2731820 * CSID:858 385 6025 * DURATION (mm-ss):01-42